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EVALUATION OF EXCITER AND CONTROL EQUIPMENT AND OFF-SET CARRIER COMMUNICATIONS TECHNIQUE

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ABSTRACT

Electrical specifications and other pertinent characteristics are evaluated for a group of equipments used for generating single sideband signals and for causing the carrier frequency to track a remote target carrier when the equipment is used with an existing AM transmitter. Comparative tests are made to determine the possibility of transmitting either single sideband or amplitude modulated signals on the same frequency as the target station frequency or off-set by 2000 to 6000 cycles so that the transmitted signals cannot be jammed separately from the target signal.

The equipment complies with the limited specifications listed by the manufacturer but fails to follow moderately evasive frequency changes of the target carrier. The equipment fails to produce single sideband signals unless the existing transmitter is unusually free from audio phase shift or compensated with custom designed equalizers.

The use of single sideband signals is found to have no advantage over the use of standard AM signals when either signal is operated in synchronism with or off-set from the target carrier frequency by 2000 to 6000 cycles. When the carriers are off-set sufficiently to reduce the severe heterodyne, one signal can be jammed independently of the other. When the two carriers are synchronized, both stations are intelligible even though a pronounced sub-sonic "flutter" limits the utility of the received signals.

PURPOSE

Two functions are served through this report. One is to show by graphs, diagrams and word descriptions, the limitations and qualifications of a group of equipments built by [redacted] 50X1

The second function is to evaluate by laboratory means, a system of "off-setting" or "snuggling" a single sideband signal to a target or "master" signal for the purpose of minimizing the effects of jamming. The evaluation of the equipment constitutes the first part of this report, and considerations of the modulation system and technique are included in the second part. These are followed by a statement of conclusions.

The testing program was conducted at the [redacted] 50X1
[redacted] during the months of January through March of 1955. All tests were of 50X1
the "closed circuit" type rather than "on the air." This type of testing permits a direct evaluation of equipment and techniques under ideal conditions without the limitations which would be imposed by radio propagation.

Basically, the system under test consists of a phase modulated radio frequency exciter and a 90 degree phase shifting audio unit which can be attached to an existing AM transmitter to produce combined amplitude and phase modulation. This method of generating single sideband signals was originally developed under Project W-28-099-AC-131 between Stanford University and the Watson Laboratories of the Air Materiel Command.[1]

In addition to the exciter equipment, the system includes an electromechanical servo system for synchronizing the single sideband carrier frequency with a target carrier frequency or for holding any one of several fixed off-set carrier frequencies.

SPECIFICATIONS COMPLIANCE TESTS

The following is a brief description of the equipment furnished by this test program, including five chassis produced by [redacted] The 50X1
Exciter Unit is a source of phase modulated radio signals and of phase shifted audio signals to be used in conjunction with an AM transmitter to produce single sideband signals through a hybrid modulation system. A power supply for the

(1) "Composite Amplitude and Phase Modulation," by Oswald G. Villard, Jr., ELECTRONICS, V. 21, No. 11, pp. 86-89, Nov., 1948.

above Exciter Unit supplies regulated DC voltages and AC filament voltages. A Control Unit furnishes a source of servo-controlled radio frequency signal sufficient to drive the Exciter Unit and includes a filtering and discriminating system to prevent the servo-system from responding to noise or modulation components in the audio signals supplied. A Conversion Unit heterodynes the receiver IF signals to the appropriate audio frequencies to determine the off-set frequency desired and includes audio output signal metering and level control. An Antenna Unit attenuates the slave or local signal at the input of the master or distant signal receiver. Equipment supplied by the contractor includes Hammarlund SP-600 receivers, a Panalyzor SB-8a to display the radio signal energy distribution, and a Magnacorder PT6-AH for recording the composite signals. Other standard laboratory equipments were employed and may be seen functionally in the test block diagram, Figure 1.

The following is a brief list of [redacted] equipment to be 50X1
tested.

Name	Model No.
Exciter Unit	None
Conversion Unit	None
Power Supply	P-1
Control Unit	None
Antenna Unit	DS-1

A guide for the specification requirement testing was taken directly from the manufacturer's instruction manuals for the various equipments under test. The same tabular form is followed here.

<u>Exciter Unit</u>

1. Chassis: Rack mounting, 19 inches wide by 12-1/4 inches high.
2. Finish: Grey
3. Input: <u>Audio</u> input of one volt at 10,000 ohms was found adequate for all tests.

Radio Frequency. Three volts at 100 ohms provided more than enough drive for all frequencies tested.

4. Output: Audio 0.5 volt at 600 ohms could be attained with mid-range settings of the audio control potentiometers.

Radio Frequency outputs of 20 volts at 100 ohms could be attained at the frequencies tested.

5. Power Requirements: The voltage and power consumption of this unit is not properly described in the manufacturer's list of specifications in that this unit required DC plate voltage and AC or DC filament voltage supplied from a separate power supply. The power requirements of this unit are 40.3 watts heater power at 6.3 volts AC or DC and 45 watts of "B" power, or 265 volts at 170 ma for high voltage requirements or a total power drain of 85.3 watts.

Power Supply Unit, Model P-1

1. Chassis for this unit is rack mounting, 19 inches wide and 5-1/4 inches high.
2. Finish is smooth grey baked enamel.
3. High voltage supply is regulated, has a panel mounted voltmeter and potentiometer control for the high voltage.
4. Power requirements are 60 cps, 117 volts. However, there is some doubt about the manufacturers power figure of 45 watts when the intended load requires approximately 85 watts. The 6.3 volt filament winding supplying the exciter unit is rated at 3.5 amps and the Exciter Unit required 5.4 amperes, plus the intermittent load of the crystal oven heater.

Conversion Unit

1. This unit is rack mounting, 19 inches wide and 8-3/4 inches high.
2. Grey wrinkle finish.
3. Input impedance was measured at 10,000 ohms whereas the specifi-

cations called for a 100 ohm input.

4. I.F.O. at 3.5 mc was measured at 1.8 volts RMS across a 50 ohm load.

5. The audio output terminals are designed to feed a 600 ohm line.

6. Audio input voltage measured at rated one volt with gain control near mid-range.

7. Power requirements are 115 volts at 60 cps at approximately 50 watts.

<u>Antenna Unit</u>

1. Rack mounting chassis, 19 inches wide by 7 inches high.

2. Grey wrinkle finish.

3. Input frequency range is 4 to 10 mc.

4. Input impedance was measured as listed below (output 100 ohms load).

	Input #1	Input #2
4 mc	91 - J50	114 - J50
7 mc	112 + J7	122 - J20
10 mc	125 - J40	81 - J1

5. Output impedance was measured as listed below (inputs loaded with 100 ohms).

4 mc	2.7 + J125
7 mc	6.6 + J420
10 mc	21.6 + J945

6. No power required.

Impedances measured with all controls at mid-range.

<u>Control Unit</u>

1. Rack mounted chassis 19 inches wide by 8-3/4 inches high.

2. The finish is grey wrinkle.

3. The input impedance is effectively 600 ohms. (Transformer specifications call for 75,000 ohm secondary load rather than 100,000 ohms).

4. Output impedance of the RF auto-transformers is satisfactory for operation into a 100 ohm termination.

5. RF output voltages across 100 ohms:

Low Band	4.5 mc	- 4.9 volts RMS
	5.5 mc	- 5.5 volts RMS
	6.5 mc	- 5.3 volts RMS
High Band	7.0 mc	- 3.9 volts RMS
	9.0 mc	- 3.8 volts RMS
	11.0 mc	- 4.9 volts RMS

6. Output frequency range is specified as 4 to 10 mc, but the limits as measured are 4.15 to 11 mc.

7. Power requirements are 115 volts 60 cps at 70 watts.

EQUIPMENT PERFORMANCE TESTS

Whereas the [redacted] gives no specifications for checking the 50X1 normal operation of the equipment, it has been possible to make the following observations on the abilities and limitations of the individual units of equipment to function in a system as described in the equipment instruction manuals.

Exciter Unit

The testing of the Exciter Unit was delayed because of servicing that had to be performed before the unit was operative. Tuning capacitors in the doubler and output stages suffered from solder splashing as well as bent plates. As received only one frequency "range" was operable. Difficulty was also encountered when operation was attempted near 5 mc because the 2.5 mc heterodyning oscillator feeds directly into the frequency doubler and output stages. Envelope observation of the modulation pattern was impossible and spurious products made reception difficult. The original task order requested the tests to be made at 5 mc but 6 mc had to be substituted for the above mentioned reason.

Power Supply

Power Supply Unit was operationally satisfactory. The 54 percent overload of one filament winding caused no fault in operation of the equipment during the period of the tests.

ANTENNA UNIT

The Antenna Unit, Model DS-1, was designed to null out the slave signal at the input of the master signal receiver. Electrically, the antenna unit consists of an RF delay line fed at each end by a coaxial transmission line from the two receiving antennas. A magnetic pickup loop is positioned along this delay line to the point that gives maximum attenuation of the slave signal. Controls are provided for vernier phasing, amplitude balancing and antenna reversing.

The Antenna Unit insertion loss and its ability to attenuate one signal by phase cancellation was measured at 4.5, 8 and 10 megacycles. At 10 megacycles, manual adjustment of the phase control became very critical, however, the average null figure achieved was as good as those made at lower frequency settings. The minimum null achieved was 40 db and the maximum (10 mc) was 64 db, the nominal figure on all the tests made was 46 db with an insertion loss of 14 db. The above special features were all laboratory tested and found to be satisfactory except as described later in relation to the specific problems encountered.

The DS-1 Antenna Unit that was supplied to the [redacted] 50X1 laboratory was not the same model as the one listed in the manufacturer's instruction book, or DS-2. References in the textual material of the instruction book are pertinent to the DS-1 and the assumption was made that the two models were electrically interchangeable. A circuit diagram of the DS-1 is shown as Figure 2, and a block diagram of the test equipment used in testing the Antenna Unit is shown as Figure 3. Considering the importance of this unit to the effectiveness of the overall control system, careful consideration of the relative radio frequency field strengths, orientation of the antenna structures, and relative directions of the signal propagation paths would be required.

Testing the Antenna Unit showed the following:

1. 15 db insertion loss on all frequencies within range of 4 to 10 mc when using single input connection.
2. Attenuation at null positions varied with frequency and mechanical repeatability of control adjustments. All null measurements were in the order of -45 db with some exceptionally high ratios of -64 db at 10 mc. However, this high ratio was not repeatable because of gross mechanical control.

Conversion Unit

Conversion Unit operation was quite satisfactory after placing the crystals in the proper sockets, IF realignment and minor modification of the channel "B" signal path. Scope monitoring of the output signals indicated that a considerable amount of IF signal was present. Integrating capacitors were not present in the diode detector output circuit so a 160 mmfd capacitor was installed across R-6, the diode load resistor. An additional RF bi-pass capacitor was installed from the audio amplifier plate, pin 6, of V-8 to ground. These modifications reduced the audio signal level slightly but removed most of the 355 kc signal from the output. A similar test was made on channel "B" but similar capacitors installed at either comparable circuit position led to a reduction of signal level that could not be tolerated in the Control Unit. The modification in channel "B" helped the motor sensitivity in frequency control. Short coaxial cables were used at the inputs of the two 6BE6 mixer stages so that no transmission line problems were encountered from the mis-match due to the 10,000 ohm resistor terminating the coaxial line.

Control Unit

Control Unit operation was finally achieved after the removal of a few errors in the original internal wiring. A sensing polarity switch that was not included in the manufacturer's schematic was found to be wired incorrectly. The switch was so connected that the output of the amplifier V-3 was always shorted. It was also discovered that the equipment as originally received had the wrong tube type installed in the socket of V-1. However, the misplaced tube could not be removed from the socket because the socket and the tube had been overheated with the result that the plastic socket had molded itself to the tube. Consequently, both tube and socket were replaced. Two "rosin" solder connections had to be repaired. Several ambiguities between wiring diagram references and text of the instruction book were resolved.

The limits of the Control Unit may be separated into two functions. First, that of motor operation and the characteristics of the circuits that control the motor limits and secondly, the characteristics of the high frequency oscillator.

The highest frequency to which the motor will respond is limited by low-pass filters whose purpose is to remove modulation components and noise that might effect a false response in the system. The filter characteristics are shown graphically in figure 4. In the frequency off-set control position, the accuracy of the 90 degree phase shift circuits made the high frequency motor response limits vary asymmetrically above and below the center signal frequency. For instance, in the 2 kc off-set position (2012 cps by measurement), the motor would respond to 129 cps below the center frequency but would not respond to frequencies more than 78 cps above center frequency.

The lowest frequency to which the motor will respond is of course determined by the ability of the motor to use power that is delivered to it. With the recommended input voltages at J-1, the lowest frequency to which the motor responded was 6 cps.

The overall limitations of the high frequency oscillator are covered in the report on the manufacturer's specifications. However, the relationship of motor control to the H.F.O. was not mentioned. The average frequency range of the motor driven capacitor is 7.7 kc when the low frequency coil is used and 15.4 kc when the high band coil is used. This range is in the same order of magnitude as the bandpass of the Hammerlund SP-600 receiver so that these two system limitations complement one another.

The motor drive speed was tested by applying two audio oscillators to the control unit input and adjusting their frequencies until the fastest rate of shaft rotation was observed. The highest speed observed required 17 seconds to turn the control capacitor shaft through 180 degrees. From this figure and the average frequency range, it may be determined that the nominal control rate would be 456 cps/sec. on the low frequency band and 903 cps/sec. on the high frequency band. The oscillator was sensitive to mechanical vibrations to the extent that walking across the floor would cause the frequency to flutter. This microphonic characteristic is clearly demonstrated in the tape recordings.

SYSTEM TESTS

The generation of a single sideband signal was first tested with the [redacted] Exciter Unit and the HT-4, Halli- 50X1 crafters Transmitter. The test results were completely unsatisfactory. Phase shift in the audio amplifier of the HT-4 was so severe that it produced almost no sideband suppression in the hybrid modulation system. Figure 5 contains photographs of an oscilloscope pattern set up to show the trapezoidal pattern of the HT-4 amplitude modulated signal. The audio phase shift is indicated by the elliptical patterns at the top and bottom of the trapezoidal figures. Distortions other than audio frequency phase shift make the exact phase shift for any given frequency hard to calculate but approximate phase shift figures are listed below:

300	-55°
500	-25°
1000	$\pm 10^{\circ}$
2000	$+37^{\circ}$
3000	$+60^{\circ}$
4000	$+74^{\circ}$

It was decided to "side-step" the HT-4 and any redesign required to make it a useable part of the single sideband system and to substitute in its place a small diode modulator which would introduce no audio phase shift. This would allow the remaining work to be directed toward an evaluation of the Pioneer Electric and Research equipment. Figure 6 is a schematic of the modulator built at Jansky & Bailey, Inc. The special feature of this modulator is that the audio signal can be kept small relative to the RF drive at the modulation point and the RF carrier component can then be balanced out to produce any percentage of modulation desired in the output signal.

Testing and reporting of the SSB system follows standard practices as far as is practicable. Besides graphs and diagrams, tape recordings are used to demonstrate the effectiveness of various control positions of the carrier "off-set" operation. A brief descriptive announcement is recorded on each tape, preceding the recording of the test transmission. The receiver was adjusted during the recording to demonstrate the sort of reception that would be possible at the receiving site.

A block diagram of the overall test equipment is shown as Figure 1. The principal radio signal paths are drawn in heavy black lines and the dotted lines represent signal paths used in occasional tests. The assumption is made in this diagram that the master signal has changed frequency by an amount Δf and the slave signal will be corrected by the amount $\overline{\Delta f}$.

Energy distributionsof the single sideband transmissions were checked at three different settings in order to show a range of control variations. The percent of modulation of the AM signal was used as a reference level and the phase modulation adjustments were made to produce an optimum suppression of the unwanted sideband components as viewed in the Panalyzor. One thousand cycles per second was the modulation frequency used for the initial adjustment. After the initial adjustments, the modulation frequency was varied between 300 and 3000 cps and the various sideband components were measured in amplitude at the frequencies indicated. In figures 7, 8 and 9 the line labeled "C+1" in the figures indicates the amplitude of the desired sideband as a percentage of the carrier amplitude. "C+2" and "C+3" indicate the amplitude of the second and third order sidebands that occur above the carrier. C-1, C-2 and C-3 indicate the sidebands that are lower than the carrier frequency and are considered in this report to be the undesired sidebands. In each case, the initial adjustments were made at 1000 cps and the changes of modulation frequency produced changes in sideband distribution. A single adjustment that would give optimum rejection of the unwanted sideband in both the "lower" and "upper" control position, was not found. The "upper" position was arbitrarily chosen for these tests and all controls were adjusted for optimum in this position.

Figure 7 illustrates the sideband distribution when an attempt was made to achieve a minimum of unwanted sideband at 1000 cps. This adjustment indicated an AM reference level of 40 percent. Sidebands C+3, C-2 and C-3 were not measurable. This setting could be recommended for use when adjacent channel interference would be a problem.

The second condition tested is shown in figure 8 and illustrates the results obtained when an 80 percent amplitude modulation was used as a basis for the single sideband adjustments. With only the amplitude modulation, no C+2 sideband was evidenced so that the high percentage of this component in the test results can be assumed to be produced in the phase modulation stage. Adjustment of the "Square Law" control had no appreciable effect on the magnitude of C+2. Operation at this level of modulation could only be recommended when the information being broadcast is more important than the consideration of the adjacent channel occupant and the audio fidelity at the reception point. Figure 9 shows the results of 50 percent AM being used as an adjustment reference, and gives no appreciable improvement over the 80 percent graph when the ratio of C+1 to C+2 are considered, however, the other sidebands are reduced to a much more tolerable ratio and this percentage of AM might be considered a good compromise for average operation. This condition was used during the tape recorded SSB transmissions.

Magnetic tape recordings were made to illustrate the various positions of carrier "off-set" transmission. In all tests, the two carriers were adjusted to the same amplitude at the input of the R-274/FRR or composite signal receiver. Local FM stations were used as a source of program material and the two signals are given some contrast through using classical music in one channel and popular music in the other. The modes of operation that are illustrated on tape are as follows:

Tape No. 1, Single S.B. & AM Off-set
Tape No. 2, Single S.B. & AM Zero Beat
Tape No. 3, AM and AM Off-set
Tape No. 4, AM and AM Zero Beat
Tape No. 5, Comparison of SSB to AM

The receiver was tuned during the recording in order to illustrate the ability of the receiver operator to separate the signals. No adjustment was made, however, except that of the main tuning dial.

Generally it may be said that signals separated by 3 kc or more could be considered as separate signals regardless of the type of modulation employed. Signals closer than 2 kc are uncomfortable to listen to and only a person of determination, listening for special information would persevere.

The system in "off-set" operation would be susceptible to jamming in the ordinary sense in that the conditions that make the desired signal readable and comfortable would also make it vulnerable. The best result would be in the "sync" or zero beat condition where carrier beats are sub-audible. Even here, however, the two signals mutually jam each other. An additional jamming signal, of course, would jam each of the two signals equally in the zero beat position.

For comparison with other receivers and to help understand the recorded results of receiver tuning, the bandpass of the type R-274/FRR receiver used in the test program was measured and is shown in figure 10. The R-274/FRR selectivity curve may be compared with the bandpass curve shown in figure 11 of a receiver from the master transmitter area that was tested in the J & B Inc. labs on a previous project.

The magnetic tapes illustrate very interestingly the sensitivity of the control unit H.F.O. to mechanical vibration of any sort. For instance, the beat frequency of the two carriers will be heard to change with a quick fluttering sound at each footstep of a person walking through the laboratory. No attempt was made to shock-mount this equipment as the manufacturer's specifications called for rack mounting.

The most obvious conclusion that must be drawn is that the [redacted] 50X1
[redacted] Control Unit H.F.O. is not mechanically stable enough to be used in the 50X1
intended application. With this one feature corrected, the equipment could be used to synchronize two carriers as long as no deliberate frequency evasion was used by the operators of the "Master" transmitter. Very satisfactory control was attained in the carrier "sync" position. The servo controlled H.F.O. would maintain control over any normal drift due to temperature changes during warmup and even followed some manual adjustment of the master transmitter frequency as long as it was not too fast or too great a frequency change. Several changes in the physical layout are recommended to improve operational flexibility and to reduce the time needed for adjustments. Control devises, i.e. dials, pots, switches, etc. could be repositioned to allow greater ease of operation and improved performance. For example, adjustments of the various exciter unit controls were cumbersome because some adjustments were only available from the back of the unit and other related adjustments were in the front. When the equipment is rack mounted, per the design requirements, scopes and meters must follow the operator back and forth as the adjustments are made. Specific Exciter Unit controls that should be repositioned are R-102, R-103 and R-106.

The Control Unit servo-controlled knob was difficult to adjust when manually setting the slave signal to the master signal. A servo motor on-off switch could be installed on the front panel to aid the operator during initial tuning and sensing control adjustments. The sensing polarity switch should also be available from the front panel to allow the operator to maintain proper sensing with the carrier off-set above or below the master transmitter frequency.

Some means of balancing out the 2.5 mc conversion oscillator at the input of the doubler-amplifier would allow operation on or near 2.5 and 5 mc without interference from this oscillator.

USE WITH EXISTING AM TRANSMITTERS

The Exciter Unit can be added to existing amplitude modulated transmitters to produce single sideband signals provided either (a) audio phase shift in the transmitter modulator is reasonably limited, or (b) a phase equalizing network can be devised for each particular installation. The practical difficulty of satisfying this requirement would be proportional to the extent of phase shift encountered in a particular installation. In some cases, the phase shift would be excessive so that the required phase equalizing network would be complicated if not impractical.

For example, the audio phase shift in the HT-4 transmitter varied from -55 degrees to +60 degrees over the frequency range of 300 to 3000 cps. In order to obtain 34 db suppression of one sideband with respect to the transmitted sideband, the phase equalizing network would be required to track the modulator phase shift within ±2.28 degrees over the entire voice frequency range. Considerable variation in phase shift with modulating frequency is typical of amplitude modulated transmitters which are designed for voice frequency communications. Transmitters of this type usually limit audio frequency response by limiting the response of the speech and modulator stages rather than by broadband amplification and bandpass filters.

AM transmitters designed for less restricted audio frequency ranges, as for transmission of music, generally have considerably less phase shift variation with frequency. In fact, in order to obtain good fidelity, many such transmitters employ a combination of internal negative feedback and overall RF feedback. Basically, the RF feedback network consists of an RF pickup probe which samples the transmitter output, a linear envelope detector, and a transmission network for feeding a portion of the detected output envelope back to the audio input terminals.

In order to operate a transmitter which employs RF feedback in the proposed manner as a single sideband transmitter, it would be necessary either to disable the RF feedback arrangement or to replace the envelope detector with a device capable of restoring the sampled signal to a double sideband wave before detection. Simply disabling the RF feedback circuit would not be satisfactory in most cases since the internal feedback alone does not usually effect the required freedom from phase shift variations.

Investigations of the phase shift characteristics of a high power AM transmitter were undertaken in the interests of this project with particular reference to the feasability of generating single sideband signals by the proposed method. The transmitter used for the tests was the Type 420A high frequency super-power transmitter manufactured by Continental Electronics Manufacturing Company. This transmitter employs a 50 kilowatt Doherty, grid-modulated, linear driver for the final linear amplifiers.

Tests of the 50 kilowatt driver showed that phase variations with audio frequency from modulator output to RF envelope are limited to +2.1 degrees from 300 to 3000 cps. Consequently, all other tests were restricted to the audio frequency circuits of the speech and modulator stages. These tests and data indicate, therefore, the phase shift to be expected between the audio input terminals and the RF envelope when the RF feedback circuits are disabled. Under these conditions, the phase shift changed by a total of 63 degrees between 300 and 3000 cps. When various high-frequency roll-off and internal feedback circuits were removed, the phase shift varied by a total of 56 degrees over the same frequency range, or less than one-half the variation found in the HT-4 transmitter. The practical significance of these results is discussed in the conclusions of this report.

CONCLUSIONS

With a few exceptions the [redacted] 50X1
equipment complies with the limited specifications contained in the associated instruction books. The carrier frequency control system is not capable of synchronizing a friendly transmitter carrier, either at zero-beat or in off-set, with a moderately evasive target carrier. This limitation is imposed by the design concept of the frequency control system. An abrupt change in target carrier frequency of 80 to 130 cycles per second will evade the follow-up of the control system. The control system will hold the friendly carrier frequency with approximately 6 to 10 cycles of the target carrier or off-set frequency provided there is no abrupt change in either frequency or no appreciably mechanical vibration or shock of the Control Unit.

The composite phase and amplitude modulation method of producing single sideband signals is not generally a practical method for converting an existing amplitude-modulated transmitter into a single sideband transmitter. The method required a 90 degree phase difference between the audio voltage producing phase modulation and that producing amplitude modulation <u>at the point of amplitude modulation</u>. Phase shifts in excess of ±11.4 degrees in the speech and modulator stages result in sideband attenuation of less than 20 db relative to the transmitted sideband. AM transmitters which employ RF feedback frequently have considerably less than this amount of phase shift but may have excessive audio phase shift when the RF feedback is removed. Any existing RF feedback arrangement would have to be removed from the transmitter for conversion to this type of single sideband service. Phase equalizing networks could be designed to track the audio phase shift of a transmitter; however, each converted transmitter would have to be compensated on a custom basis.

The relatively strong second-order sideband on the same side of the carrier as the transmitted sideband could not be reduced by use of the "Square Law" circuit. The amplitude of this spurious sideband was measured and found to be 27 percent of the transmitted sideband (-11.3 db) as compared with the theoretical 30 percent (-10.4 db) for sine wave modulation. The slight improvement could hardly be attributed to the "Square Law" circuit since this circuit failed to influence the sideband amplitude one way or another. No conclusions concerning the potential usefulness of such a square-law device will be attempted here.

Tests of the "snuggling" technique indicate that there is no significant difference in the effectiveness of single sideband with carrier as compared with double sideband with carrier when used against a standard amplitude modulated target signal. Suppression of the sideband closer to the target carrier results in slightly less interference to the target signal.

When the carriers are offset by 2000 cps, very little can be done by receiver tuning to minimize the severe heterodyne and the results are more or less mutual jamming. With carrier separation of 3000 cps the listener can separate the two signals to a certain extent, but the interference between the two reduces the effectiveness of both. With carrier separation higher than 3000 cps, the two signals become essentially separate, closely adjacent channel stations.

When the carriers are synchronized within 5 or 6 cps, both signals are intelligible even though the quality of the recovered signals is limited by the low frequency "flutter" between the carriers. Whereas there is no appreciable difference in the use of single or double sideband, the results are significantly better than have been observed previously[1] with double sideband suppressed carrier. Presence of the friendly carrier insures the existence of an in phase component of carrier for demodulation of the friendly signal and largely prevents the severe distortion which results from a 90 degree phase shift between carrier and the double sideband resultant.

Respectfully submitted,

and

May 19, 1955

50X1

[1] Final Report, Task I, dated Nov. 7, 1951

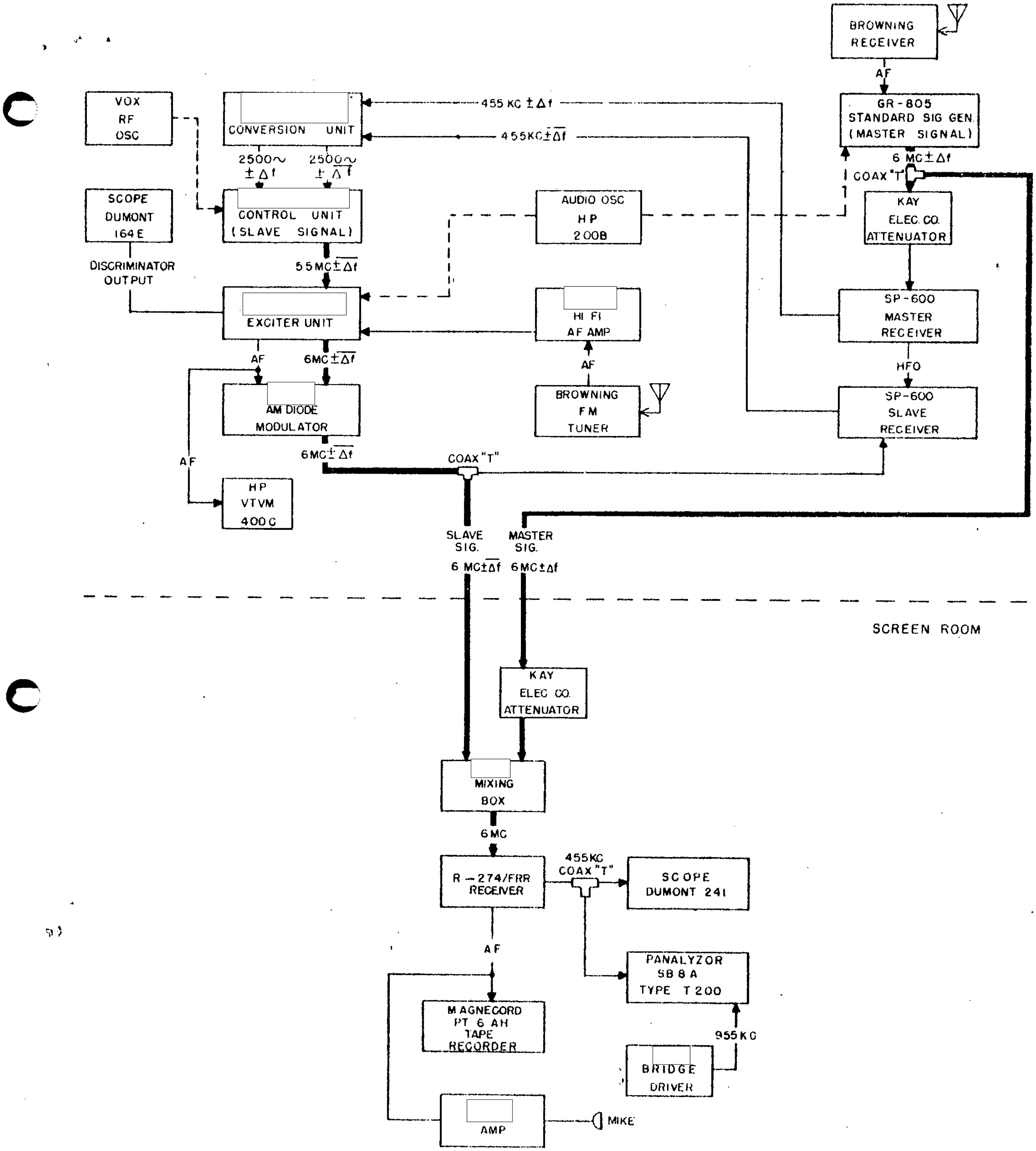

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FIG I

BLOCK DIAGRAM OF TEST EQUIPMENT

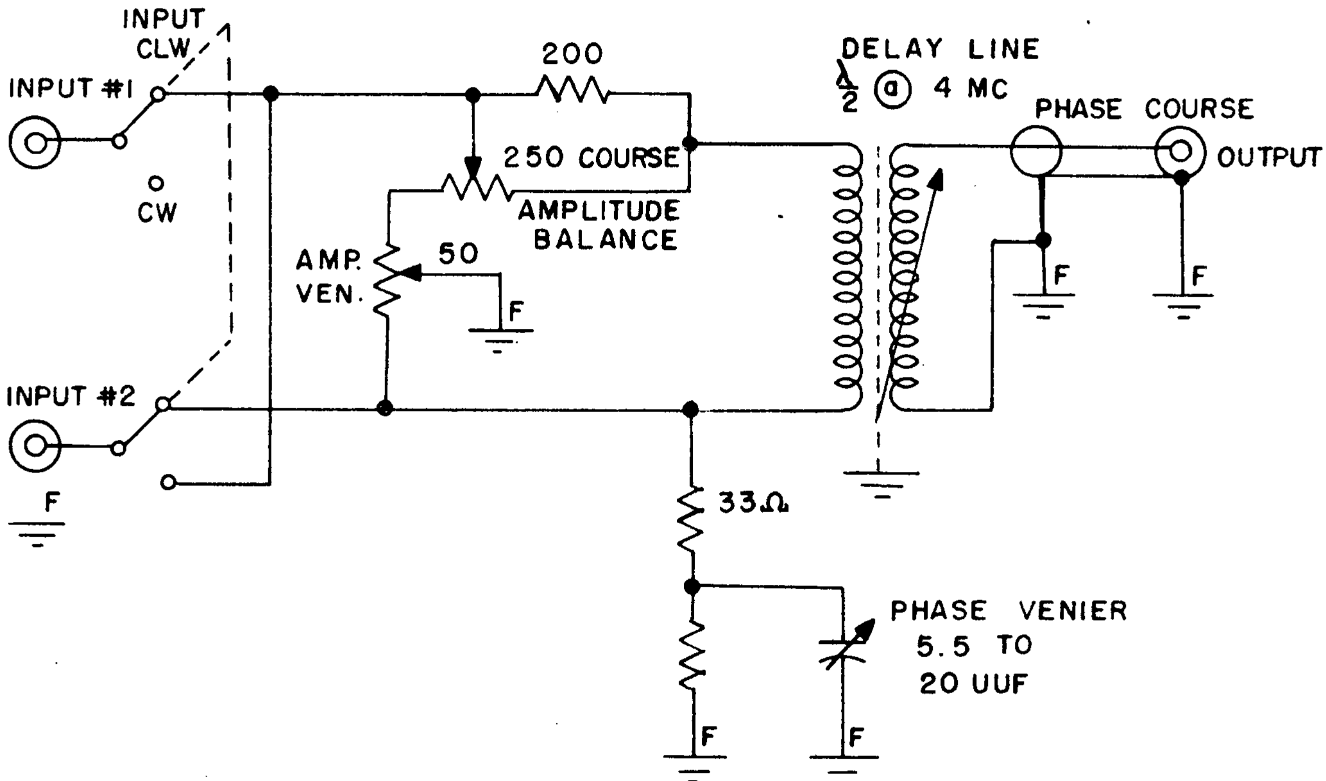

FIG. 2

SCHEMATIC OF ANTENNA UNIT DS-1

[redacted] 50X1

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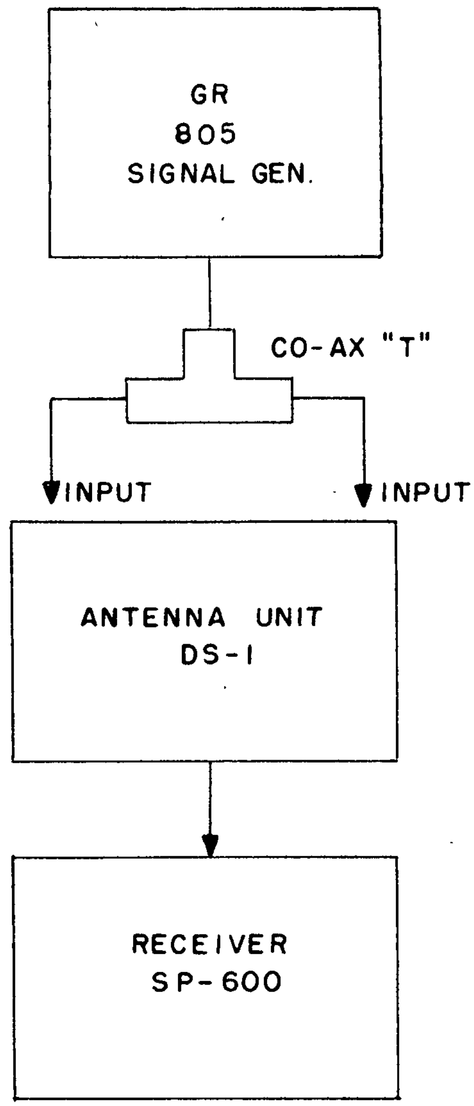

FIG. 3

BLOCK DIAGRAM OF TEST EQUIPMENT
USED WITH ANTENNA UNIT

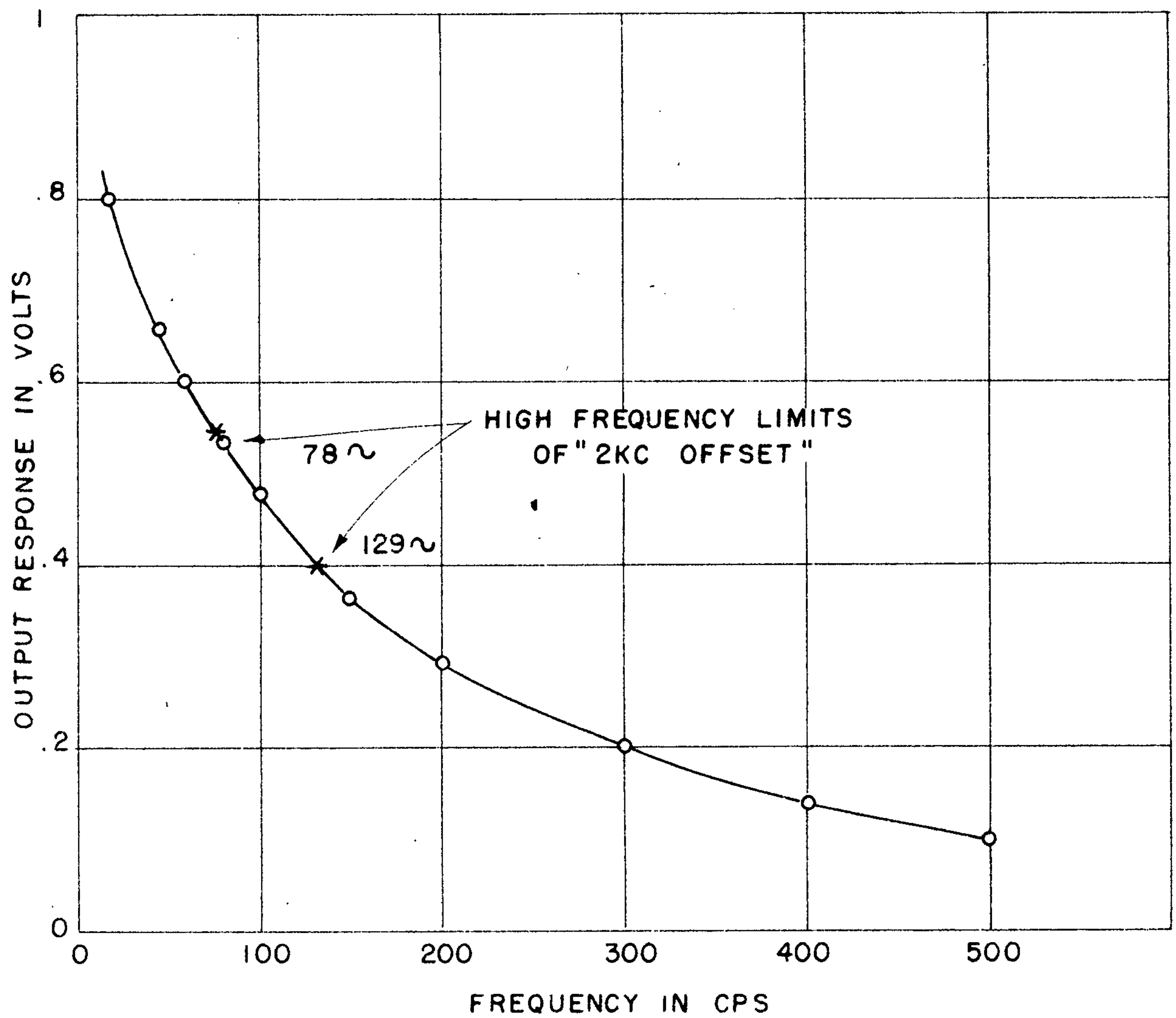

FIG. 4

[redacted] CONTROL UNIT LOW PASS
FILTER RESPONSE CURVE

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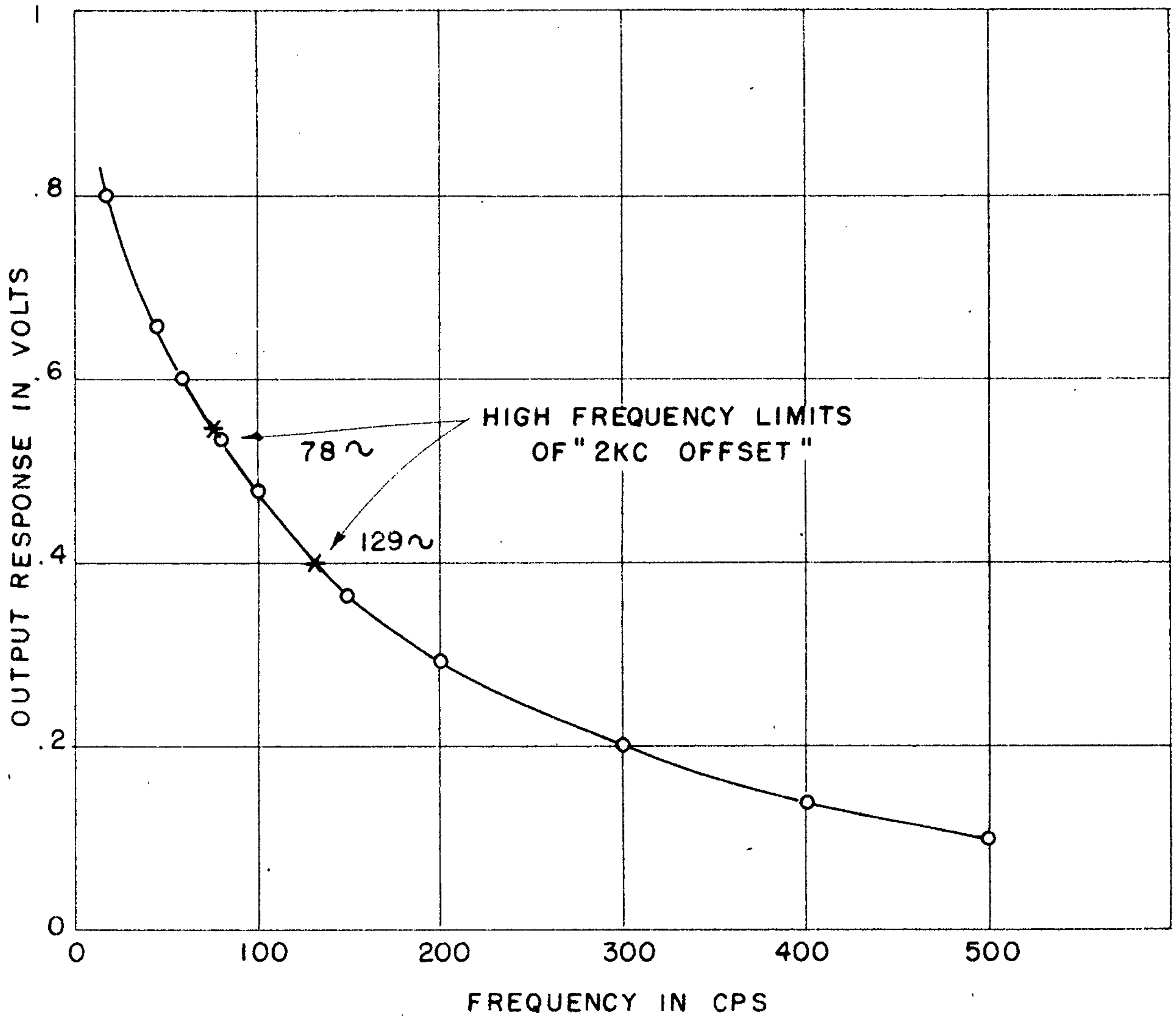

FIG. 4

CONTROL UNIT LOW PASS FILTER RESPONSE CURVE

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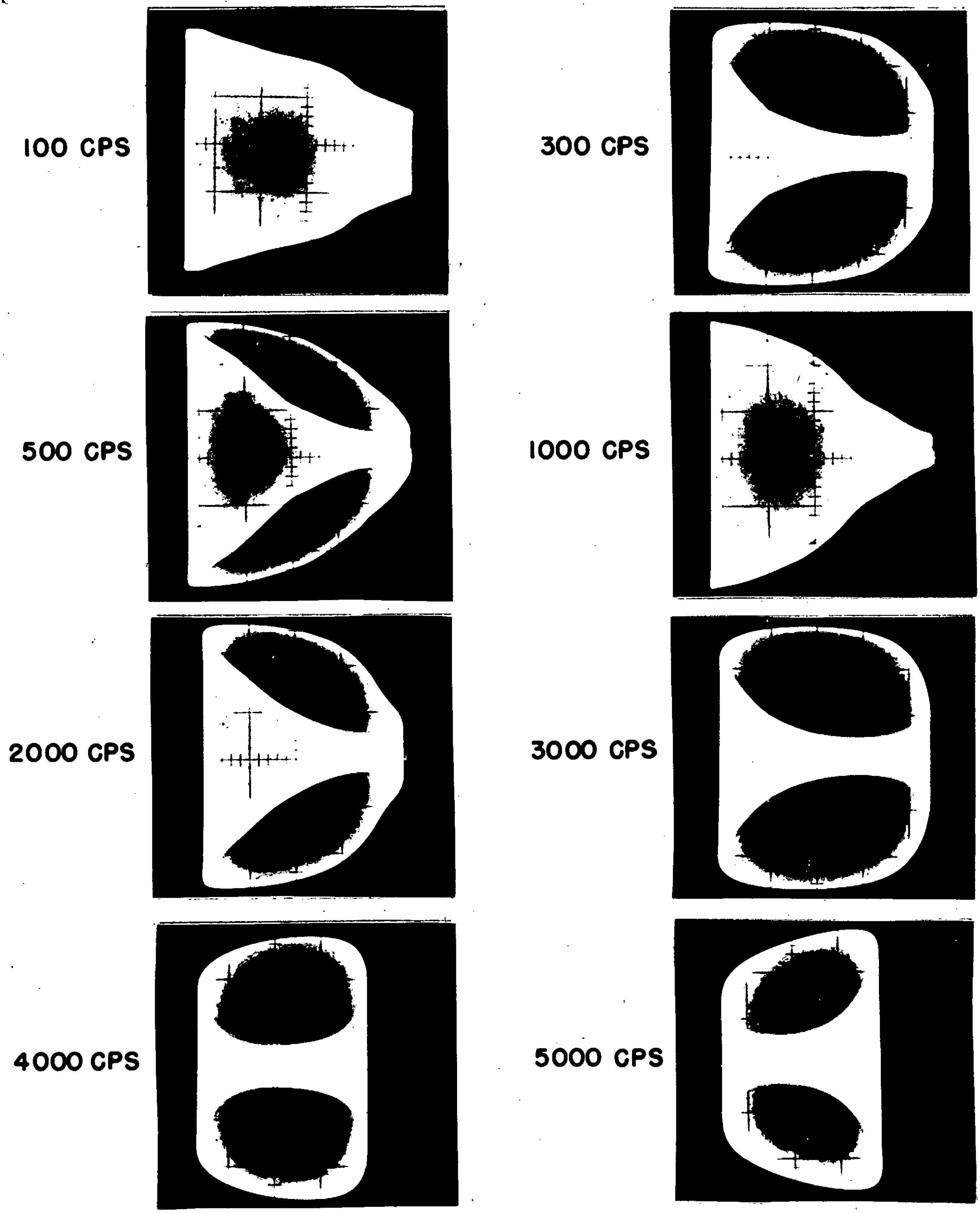

FIG. 5
TRAPEZOIDAL MODULATION PATTERNS OF THE HT-4 TRANSMITTER

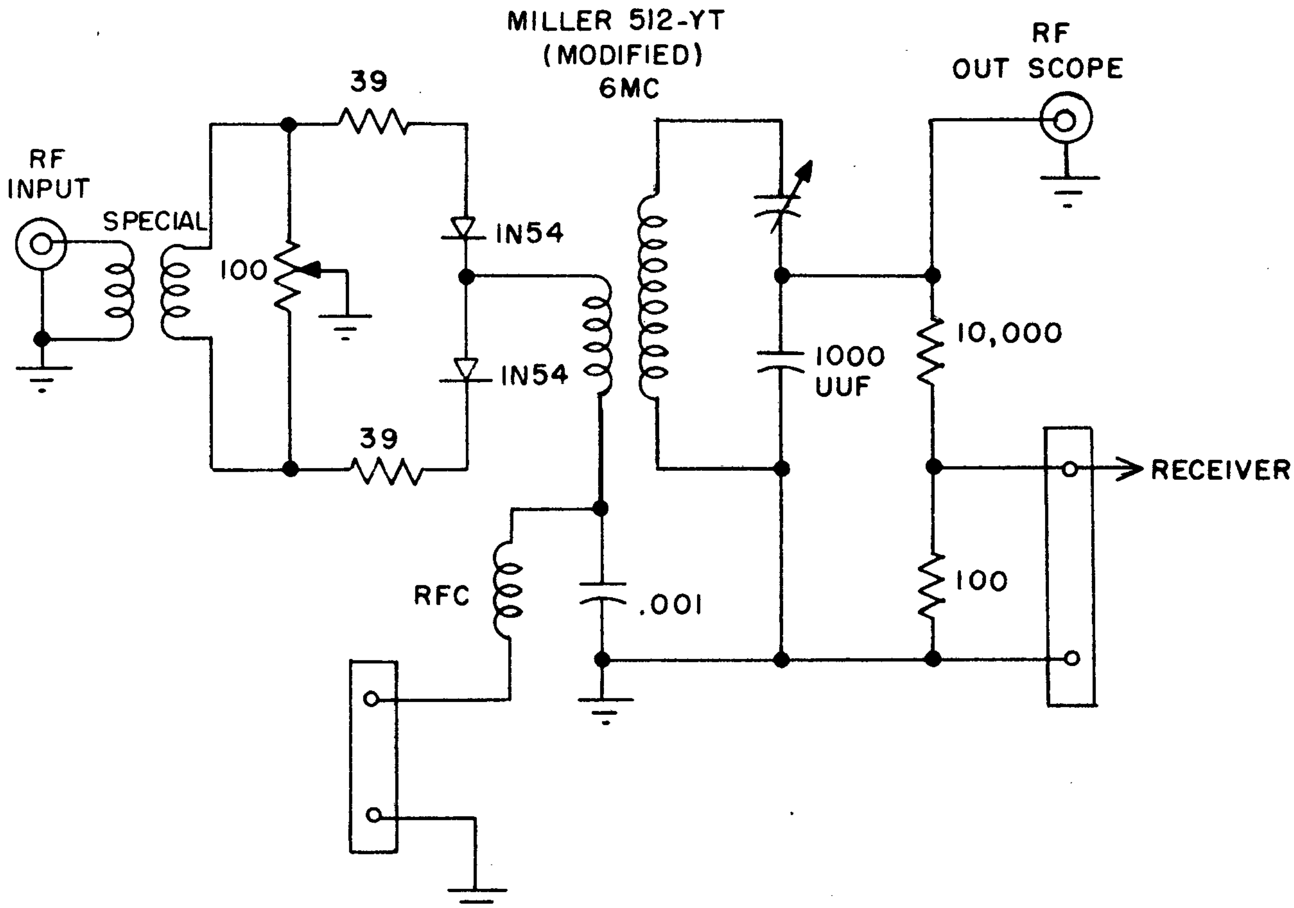

FIG. 6
BALANCED MODULATOR

50X1

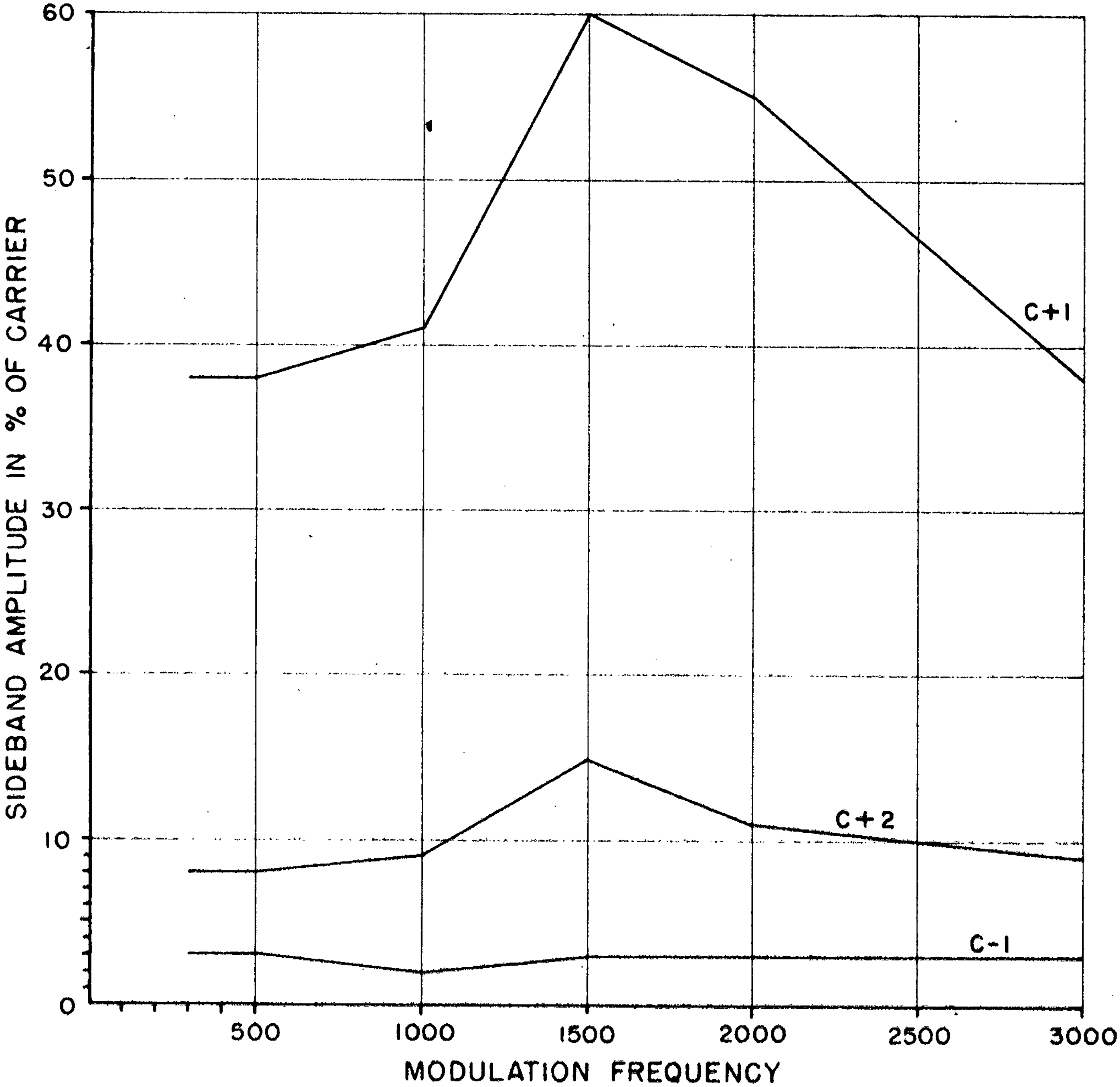

FIG. 7
EQUIPMENT ADJUSTED FOR MINIMUM OF UNWANTED SIDEBAND

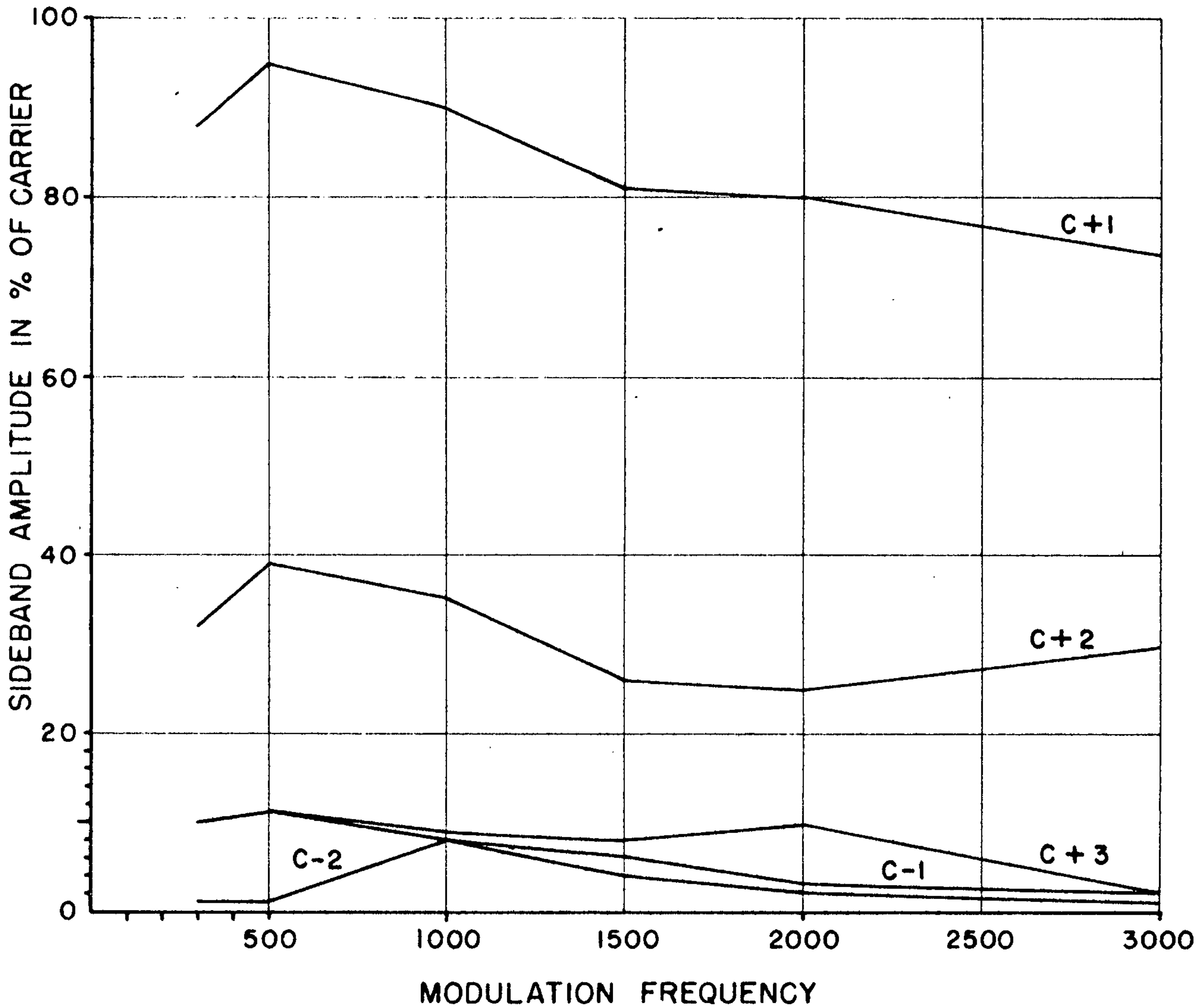

FIG. 8

EQUIPMENT ADJUSTED FOR OPTIMUM WITH
AM MODULATION OF 80% AT 1000 CPS

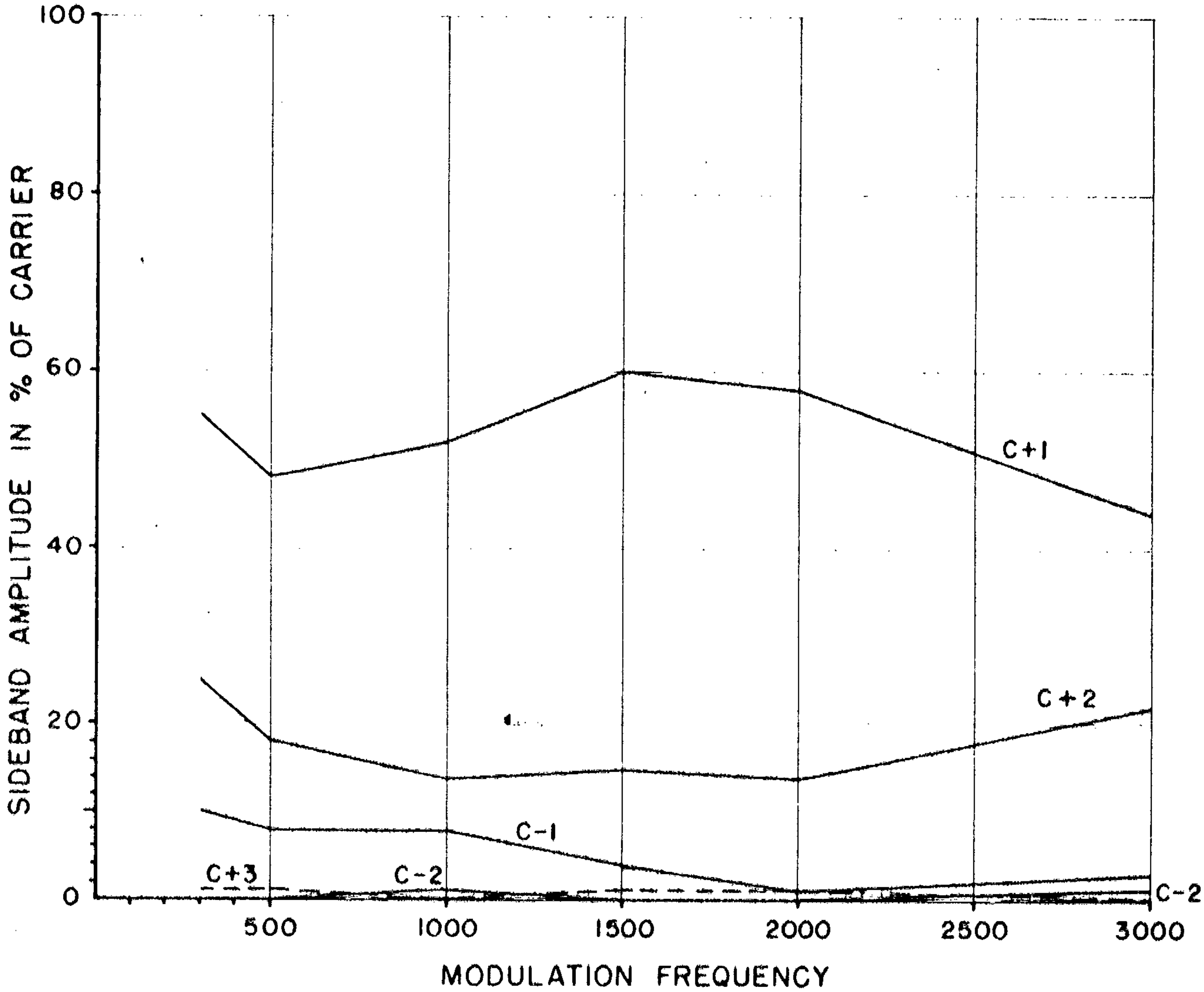

FIG. 9

EQUIPMENT ADJUSTED FOR OPTIMUM WITH
AM MODULATION OF 50% AT 1000CPS

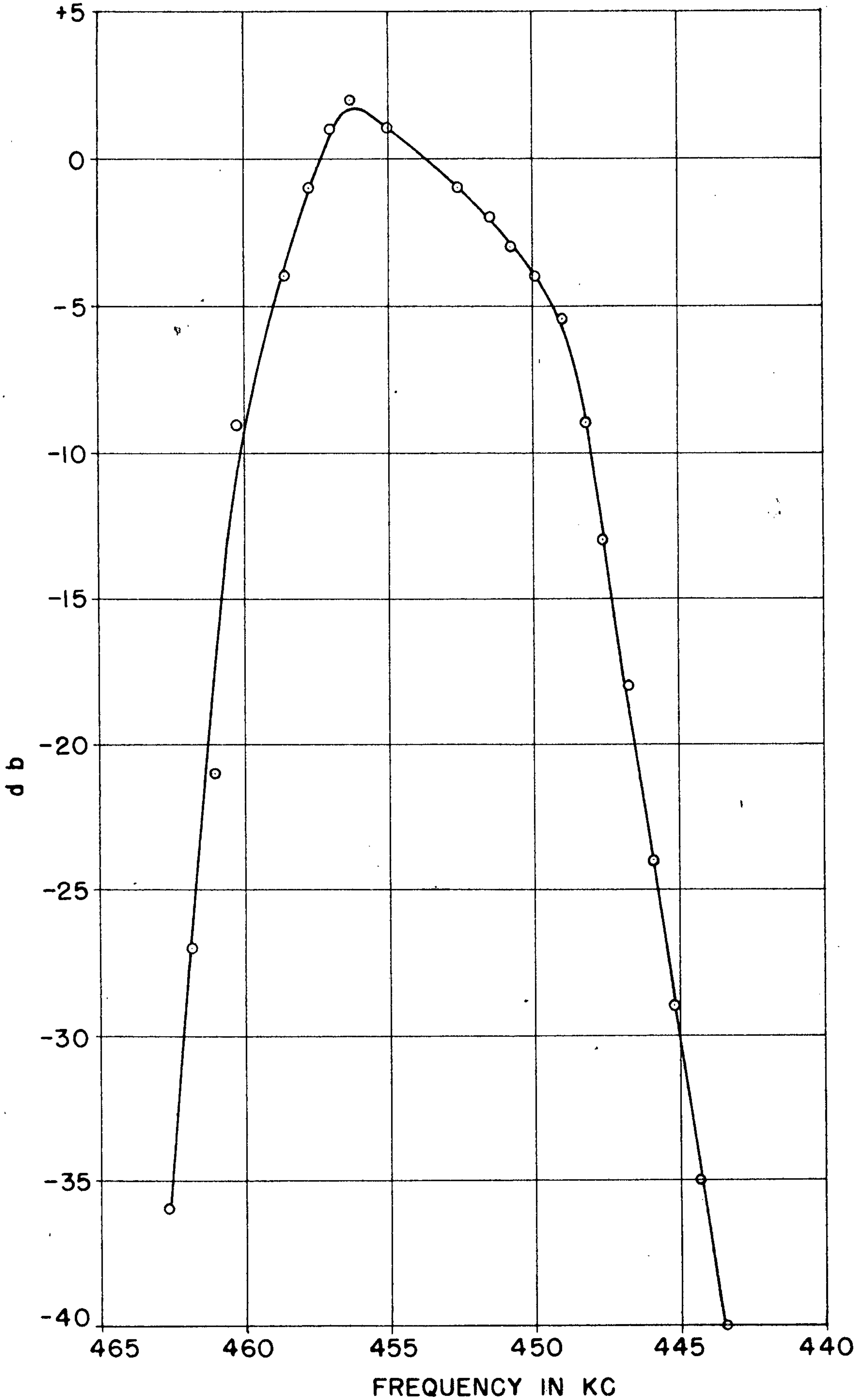

FIG. 10

I.F. CHARACTERISTICS OF R-274/FRR

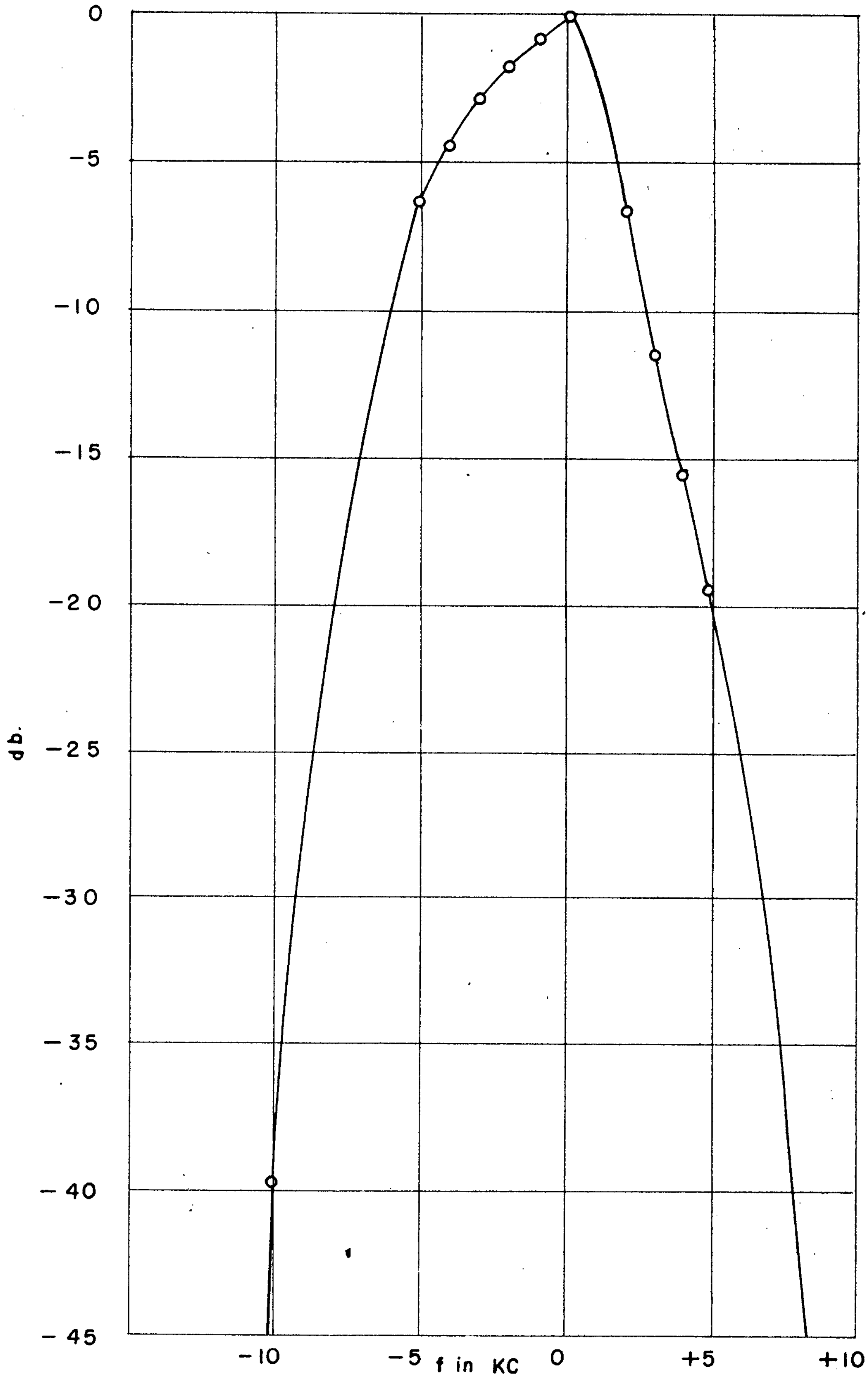

FIG. 11
IF CHARACTERISTICS OF A REPRESENTATIVE FOREIGN MADE RECEIVER